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## PATENT SPECIFICATION

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## COMPLETE SPECIFICATION

## Improvements in or relating to Fuel Compositions

We, APOLLO CHEMICAL CORP., a corporation organized under the laws of the State of New York, one of the United States of America, of 250 Delawanna Avenue, Clifton, State of New Jersey, United States of America, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to fuels having improved combustion characteristics and in which the adverse effects of combustion products on the structures with which they come in contact are reduced. The invention is particularly, though not exclusively, advantageous in connection with the use of fuel for motive power purposes, where the combustion products of the fuel are used either to produce steam or to act directly on turbine wheels.

Fuels are usually burned in enclosures lined with refractory material and the products of combustion make contact with that refractory lining. The products of combustion then pass from the furnace to a utilization area. Sometimes this utilization area comprises the tubes of a steam generating system, the products of combustion passing around those tubes and transferring the heat which they carry to the water in the tubes, changing that water to steam or superheating already-formed steam. In other instances the utilization chamber comprises a turbine, with the products of combustion directly impinging against the blades of the turbine. Wherever the products of combustion engage a structural element an interaction between them can take place, depending upon their respective natures. After this interaction has deleterious effects, and the extent of those effects depends to an appreciable extent upon the chemical content of the original fuel and the temperature of the combustion products. Even traces of such elements as vanadium, sodium

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and sulphur in the fuel produce troublesome, and often exceedingly disadvantageous, effects on the structures with which the combustion products come into contact.

In some instances the combustion products react with the refractory bricks in the furnace or with the cement which holds those bricks together in order to deteriorate either the bricks, cement or both, thus hastening the day when the furnace must be closed down and relined, an exceedingly expensive operation. Contact between the combustion products and the fireside boiler tubes, as well as the economizers, preheaters and stacks of boilers, produces corrosion of those metal structures, hastening the day when the furnace must be shut down so repair or replacement of these structural elements can be carried out. This corrosion is intensified when the combustion products form deposits, usually sticky and tenacious in nature, on these structural elements. The combustion products will also tend to form ash deposits which not only have a corrosive effect, but also tend to accumulate and block the passages through which the hot gases are designed to pass.

The problems produced by these combustion products are generally well recognized. It is believed that various chemical reactions are involved. Thus the formation of low melting point deposits on the furnace walls and furnace supports are believed to act as fluxing agents and mineralizers on hot refractory material, leaching out the refractory components and dissolving the adhesive between the refractory bricks. Moreover, it is believed that these low melting slags cause low temperature condensation of corrosive sulphuric acid to take place, thus intensifying the breakdown of the refractory material. The corrosion of such structural elements as fireside tubes, economizers, stacks and the like result from comparable causes.

The problems involved are particularly acute in connection with gas turbines operating with

residual fuels, where the gaseous vapors laden with sodium, vanadium, and/or sulphur-containing ashes form deposits on the turbine blades which not only corrode those blades but also impede proper turbine action. The problems involved are also particularly acute in steam boilers of marine vessels where, because of space limitations, the superheater tubes are spaced quite close to one another with only narrow passageways between them. Ash which builds up on the superheater tubes will cause blockage of those narrow passageways, necessitating a costly and laborious cleaning-out period, and the greater the density and tenacity of that ash, the more difficult is the cleaning operation. In any boiler the build-up of ash on the tubes, in addition to impeding the flow of hot gas between the tubes, also acts adversely upon the transfer of heat through the tubes, thus reducing the efficiency of the boiler.

One approach which has been taken to this problem in the past has been to add substances to the fuel which would react or coact with the troublesome combustion products in order to minimize their adverse effects. Thus, it has been proposed that there be injected into the fuel or firing zone comparatively massive dosages of materials such as the oxides, hydroxides, carbonates and other salts of magnesium, calcium, aluminum, zinc, sodium, silicon, manganese and various of the rare earth metals. The addition of clays such as dolomite, talc and magnesias has also been suggested. These procedures, however, have not proved satisfactory, largely because the dosages of beneficial metal which must be added if any appreciable desirable effects are to occur have been excessive. For example, the addition of magnesium, as previously suggested, involves the use of 3 mols of magnesium for each mol of vanadium in the fuel. Such relatively massive dosages of additive have not only involved excessive cost insofar as the materials themselves are concerned, but various secondary adverse effects exist—the large amounts of additive themselves produce appreciable quantities of dense, tenacious ash which tend to block the passages between the tubes; when the additive is added to a fuel oil, the fuel oil pumps exhibit excessive wear; the handling of such large amounts of additive involves an excessive amount of care and attention on the part of maintenance and operation personnel. Moreover, in many instances the results promised by the proponents of such additives did not materialize, or else did not reliably materialize in all instances.

An object of the present invention is to devise a fuel composition containing an additive which will reliably overcome the adverse effects of vanadium, sulphur and sodium contents of fuels at least to a substantial degree, and which will involve the use of con-

siderably smaller amounts of additive materials than have heretofore been thought possible.

The invention is applicable for use with residual petroleum fuel, coke and coal having vanadium, sulphur and/or sodium content. The precise manner in which the additive is provided is not critical. It may be combined with the fuel before combustion (mixed with a liquid fuel or coated, either in liquid or powdered form, onto a solid fuel), it may be injected into the furnace concurrently with the fuel, or it may be injected separately into the furnace just beyond the fire zone.

It has been discovered that when the additive comprises a specific combination of substances provided in particular relative proportions, one of the constituents being present in much greater proportions than either of the other two constituents, surprisingly effective results are obtained despite the fact that all of the constituents are used in much smaller proportions than has been previously proposed in the prior art. The substances in this composite additive combine or coact with the deleterious combustion products in such a way as to result in the production of an ash which is porous, light and non-tenacious, and which therefore produces much less corrosion, and much less built-up and passage-blocking accumulations, than has previously been thought possible.

The composition of this invention contains a minor amount of an additive, comprising a first constituent which consists of one of the elements aluminum, magnesium or manganese or a compound or compounds of said one element, a second constituent which consists of one of said elements or a compound or compounds thereof which can constitute said first constituent, other than the element or a compound or compounds thereof selected as said first constituent, and a third constituent consisting of the element iron or a compound or compounds thereof. The first constituent is present in the composition in major proportions compared with either of the second and third constituents, but in appreciably lesser proportions than has heretofore been taught as a fuel additive. The second and third constituents are present in the composition in comparatively minor proportions. Thus when the first constituent contains aluminum, the second constituent may contain manganese. When the first constituent consists of manganese or a compound or compounds thereof the second constituent may consist of aluminum or a compound or compounds thereof. The third constituent in each case consists of iron or a compound or compounds thereof. The first constituent is present in the additive in an amount such that the proportions by weight of its active element (aluminum, magnesium or manganese)

is from 5 to 30% of the weight of the entire additive, whereas the second and third constituents are each present in active element proportions by weight of from 0.35 to 10% of the additive. In a typical use of such an additive with a fuel having a given vanadium content, the additive is used in such proportions with the fuel, and the constituents are present in the additive in such proportions, that the weight ratios of the active element of the first constituent to the vanadium content of the fuel is as 1:2, the second and third constituents being present in weight ratios of 1:14—20. By active element proportion is meant the quantity of the free element or the combined element when a compound thereof is used, present in the additive.

In order to indicate the substantial difference between the amounts of essential additive constituents required in accordance with the present invention and those called for in the prior art, the following comparison is presented: Prior art suggestions for the use of aluminum oxide called for the use of at least 2 mols of aluminum for each mol of vanadium in the fuel, with the use of 3 mols of aluminum per mol of vanadium being preferred. In accordance with this invention, when aluminum constitutes the first constituent of our additive, a mol ratio of aluminum to vanadium or approximately 1:1 is utilized. Similar comparisons may be made between prior art suggestions for the use of magnesium or manganese compounds, and the additives used in the compositions of the present invention where magnesium or manganese compounds constitute the first constituent of the additive.

The reasons for the surprising beneficial results obtained through the use of such small amounts of essential additive constituents are not known with certainty, and the instant invention may therefore be considered as empirical in nature. It may be that there is a catalytic or synergistic effect involved. It is believed that the addition of the very small amounts of the second and third constituents so alters the way in which the first constituent reacts with the deposit-forming components of the fuel as to produce the porous, light and non-tenacious ash which is characteristic of the use of this invention. That ash is much more easily removed from furnace and boiler walls through routine cleaning steps (soot blowers or simple air lancing) than are the ashes produced in accordance with prior art teachings. Moreover, the ash produced in accordance with the present invention appears to be far less reactive, and to have a far smaller corrosive effect on the refractory materials, cements and metal surfaces of furnaces, boilers and turbines, than has heretofore been the case.

The active element used in the additive employed in the composition of the present invention is normally provided in the form of oxides, hydroxides, or carbonates of the active elements involved. The aluminum-containing compounds are preferably in the form of specially precipitated alumina, hydrated alumina (often in the form of by-product slurries), finely calcined aluminum oxides, and aluminum-containing clays such as bauxite. The particle size of the aluminum-containing active component is preferably between 0.1 and 15 microns, with a particle size range between 0.5 and 3 microns giving superior results. Optimum particle size appears to increase the porosity of the ash which is formed. The magnesium-containing constituent is preferably in the form of finely pulverized or finely precipitated magnesium oxide from sea water extraction, calcined magnesium oxides and hydroxides, preferably from naturally occurring magnesite ores or derived from sea water, magnesium carbonate or basic magnesium carbonate. The manganese-containing compounds are preferably in the form of naturally occurring or derived manganese dioxides or manganese-containing clays, as well as manganese dioxides by-product slurries derived from refining. The particle size of the manganese-containing substances is preferably between 0.1 and 15 microns.

The iron-containing compounds are preferably in the form of natural or artificial ferric, ferrous, or ferrous-ferric oxides or ferrous carbonate, but it can also be in the form of an oil-soluble iron tallate, naphthenate, sulfonate, or carbonyl, or even metallic iron, preferably present in particle sizes between 0.1 and 10 microns.

A typical additive will comprise the above constituents mixed with a liquid in which those constituents are dissolved or dispersed, and to which mixture other substances may be added, as is known in the field, for various known purposes. Typically the additive will further comprise a diluting oil or solvent together with a surfactant, a glycol, a gelling agent, a hydrophilic colloid and water.

The following Examples 1—3 describe the compounding of typical additive mixtures for use in fuel compositions in accordance with the present invention, Example 1 utilizing an aluminum-containing substance as the first constituent and a manganese-containing substance as the second constituent, Example 2 utilizing a magnesium-containing substance as the first constituent and a manganese-containing substance as the second constituent, and Example 3 utilizing a manganese-containing substance as the first constituent and an aluminum-containing substance as the second constituent.

## EXAMPLE 1

To a high-shear mixer such as a Hockmeyer, Cowles Dispersator, Banbury, Morehouse, or Premier Colloid mill, or to an

attritor such as a batch size or continuous ball mill, a sand mill or a pebble mill, or to a three-roll paint mill, the following charge is mixed and passed through:

10	14.0 parts by weight	Surfactant
	22.0 parts by weight	Diluting oil or solvent
	6.0 parts by weight	Diethylene glycol
	1.5 parts by weight	Gelling agent or pigment stabilizers
	40.0 parts by weight	Hydrated alumina
15	2.0 parts by weight	Iron oxide
	3.0 parts by weight	Manganese dioxide

Mix for a period of  $\frac{1}{2}$  to 3 hours, and then add to the charge as follows:

3.0 parts by weight	Hydrophilic colloid
8.5 parts by weight	Water

20 The resultant product will be liquid and fluid at room temperatures with less than 1% settling after six months.

## EXAMPLE 2

Follow procedure of Example 1—use following charge:

25

	4.5 parts by weight	Surfactant
	18.0 parts by weight	Diluting oil or solvent
	7.5 parts by weight	Ethylene glycol monomethyl ether
	0.3 parts by weight	Gelling agent or pigment stabilizer
30	38.0 parts by weight	Magnesium hydroxide
	1.0 parts by weight	Iron oxide
	1.5 parts by weight	Manganese dioxide

followed by:

35	2.5 parts by weight	Hydrophilic colloid
	26.7 parts by weight	Water

## EXAMPLE 3

Follow procedure of Example 1—use following charge:

40	18.0 parts by weight	Surfactant
	27.0 parts by weight	Diluting oil or solvent
	11.0 parts by weight	Ethoxy triethylene glycol
	1.0 parts by weight	Gelling agent or pigment stabilizer
	26.0 parts by weight	Manganese dioxide
45	3.0 parts by weight	Iron oxide
	6.0 parts by weight	Hydrated alumina

followed by:

0.5 parts by weight	Hydrophilic colloid
7.5 parts by weight	Water

50 The specific parts by weight set forth in Examples 1—3 are but typical. The surfactant can be provided in a range between 2 and 25 parts, the diluting oil or solvent in a range between 10 and 40 parts, the glycol in a range between 2 and 15 parts, the gell-

ing agent or pigment stabilizer in a range between 0.1 and 3 parts, the hydrophilic colloid in a range between 0.2 and 4.0 parts and the water in a range between 6 and 30 parts.

The surfactant may be any substances known 60

- to have such properties. Particularly effective are the ammonium, amine, hydroxyl amine, quaternary amine, calcium, magnesium, zinc or barium salts of (a) tall oil fatty acid, naphthenic acids, octoic or ethylhexoic acids, long chain or oil-soluble carboxylic (fatty) acids of natural or synthetic origin; (b) sulfonic acids of petroleum or synthetic origin; (c) oil-soluble alkyl phenols, as well as organic phosphorous compounds, phosphorous-sulphide treated olefins, non-ionic oil soluble surfactants and cationic oil-soluble surfactants, many of which are disclosed in British Patent 846,174 of August 24, 1960.
- Typical diluting oils or solvents are volatile petroleum distillates, pale oils preferably of naphthenic origin, cresylic acid solvents from coal tar distillations, and liquid amines.
- Typical glycols which may be used are ethylene glycol, propylene glycol, hexylene glycols, etc., glycerol, glycol ethers and glycol esters (cellosolves and carbitols).
- Typical gelling agents which may be used are various organophilic bentonites, aluminum stearate, zinc stearate, and various polymethacrylate derivatives.
- Typical hydrophilic colloids which may be used are magnesium aluminum silicates, hydrophilic bentonites, synthetic resins having a high water-absorptive capacity, starches and modified starches and gums, carboxymethyl

celluloses, and Carbopols (B. F. Goodrich Co.).

In lieu of water, glycols can be substituted completely, but a highly polar water phase is preferred in order to "swell" the pigments so that they will remain suspended in the vehicle without coalescing.

The precise form in which the additive is provided is not critical. Thus it may be provided as a dispersion of the active constituents in an oil phase, as an aqueous emulsion of those constituents, or as a dry mixture.

Set forth below in Table I are the range of proportions by weight of the active constituents of the additives for Examples 1, 2 and 3 above, Example 1 having an aluminum-containing substance as its first or major constituent and having a manganese-containing substance as its second constituent, Example 2 having a magnesium-containing substance as its first constituent and a manganese-containing substance as its second constituent, and Example 3 having a manganese-containing substance as its first constituent and an aluminum-containing substance as a second constituent. That table also shows the proportions by weight of typical actual compounds which may be used to provide the active elements in question. Table II is similar except that it shows a preferred range of the constituents in question.

TABLE I  
General Range

	Ex. 1	Ex. 2	Ex. 3
% Al	5 — 25	—	0.5 — 5.0
% Mg	—	10 — 30	—
% Mn	0.5 — 5.0	0.5 — 5.0	5 — 25
% Fe	0.35 — 3.5	0.35 — 3.5	0.35 — 10
Above provided by:			
% Hydrated alumina	15 — 75 <sup>(1)</sup>	—	1.5 — 13
% Mg(OH) <sub>2</sub>	—	25 — 75 <sup>(2)</sup>	—
% MnO <sub>2</sub>	0.8 — 9.0	0.8 — 9.0	9 — 40
% Fe <sub>2</sub> O <sub>3</sub>	0.5 — 5	0.5 — 5	0.5 — 16

- (1) The use of 75% hydrated alumina to supply 25% aluminum metal would be somewhat high in order to produce a fluid end product. For this case, calcined alumina or a mixture of hydrated alumina and calcined alumina would be preferable in order to leave room for solvent to liquefy the product.
- (2) Here again 75% of magnesium hydroxide would not leave room for solvent and calcined magnesium oxide would be required.

TABLE II

## Preferred Range

	Ex. 1	Ex. 2	Ex. 3
% Al	9 — 15	—	0.6 — 3.0
% Mg	—	15 — 20	—
% Mn	0.9 — 3	0.9 — 3.0	9 — 15
% Fe	0.6 — 2	0.6 — 2.0	1 — 4
Above provided by:			
% Hydrated alumina	28 — 45	—	2.5 — 7.5
% Mg(OH) <sub>2</sub>	—	38 — 40	—
% MnO <sub>2</sub>	1.5 — 5	1.5 — 5	15 — 30
% Fe <sub>2</sub> O <sub>3</sub>	0.9 — 3	0.9 — 3	1.6 — 7.0

- If desired the additives may also contain additional substances which produce additional known beneficial results. Indeed, when such known substances are included in the additive, it has been discovered that they may be used in much lesser proportions than has heretofore been thought necessary in order to produce their desired specific results.
- Thus zirconium or zircons may be added to increase the melting points of the oil-ash complexes or to alter the structural patterns of the oil-ash complexes. 1—5% of zirconium silicate or zirconium oxide are highly effective in this regard, and even at the highest percentages in a typical installation only one part of zirconium would be provided for 8 parts of vanadium in the fuel. This compares most favorably with the zirconium: vanadium ratio of 1:3.5 which has previously been suggested.
- Talc may be added to stabilize the oil or aqueous dispersion of the additive combination. Only 1—5% of talc need thus be added when it is desired.
- Additional small amounts (1—5%) of magnesium-containing compounds in the forms of oxides, hydroxides, carbonates or naphthenates may be added to the additives of the type of Examples 1 and 3 in order to assist in the neutralization of sulphur trioxide in the low temperature sections of the boilers.
- From 1 to 10% of antimony oxide, or certain known arsenic or chlorine compounds, may be added to produce their known poisoning effect on the catalytic activity of iron- and vanadium-containing slags in connection with the conversion of sulphur dioxide in the fuel gases to sulphur trioxide.
- From 1 to 10% of lime or dolomite or other calcium compounds can be added to perform their known ash modification function. Kaolin, colloidal silica and organo-silicones may likewise be added in similar quantities for similar purposes.
- In all of these instances the amounts of such additives are far below that previously taught as necessary in order to produce beneficial effects, whether used alone or in combination with other prior art additives.
- The amount of additive to be combined with the fuel will depend upon many factors, such as the operating temperature of the superheated steam, the design of the boiler, the burner configuration, and, of course, the impurity content of the fuel. The higher the operating temperature of the superheated steam the greater is the tendency toward the formation of slag and the corrosion of the tube supports or hangers. With narrowly spaced superheater tubes the tendency to clog the passage between the tubes is greater. The configuration of certain boilers, and particularly marine boilers, is such, primarily because of compact design, that good flame patterns do not occur and as a result there is a heavy ash accumulation and rapid deterioration of the brickwork. The greater the vanadium, sodium and/or sulphur content of the fuel, the greater is the tendency toward the production of deleterious combustion products. The amount of additive to be combined with the fuel will, of course, be

greater as any of these disadvantageous situations increases in intensity.

In a typical installation one gallon of additive (weighing 10—11 lbs), and consisting of approximately 50% active solids, is added to 4000 gallons of residual petroleum fuel. To put the matter another way, a typical residual fuel may have a vanadium content of 100 parts per million, a sodium content of 25 parts per million and a sulphur content of

2 parts per hundred. With such a fuel, additive is combined in proportions of 0.035% by weight of additive to fuel.

With these proportions, there is set forth below in Table III the percentages by weight of active element constituents of the additives of Examples 1, 2 and 3 above as its active elements are present in the fuel-additive combination.

TABLE III

	Ex. 1	Ex. 2	Ex. 3
% Al	0.005	—	0.00069
% Mg	—	0.005	—
% Mn	0.0006	0.0006	0.005
% Fe	0.00045	0.00045	0.00068

Set forth below in Table IV are the weight ratios of active element constituents to the vanadium content of the fuel after the additive has been combined therewith.

TABLE IV

	Ex. 1	Ex. 2	Ex. 3
Al/V	1/2	—	1/14
Mg/V	—	1/2	—
Mn/V	1/16	1/16	1/2
Fe/V	1/20	1/20	1/14

In the additive of the type exemplified by Example 3, in which the manganese-containing compound constitutes the first or major constituent, it will be noted that the third, or iron-containing, constituent is present in somewhat larger proportions than in additives of the types of Examples 1 and 2, in which aluminum and magnesium respectively comprise the first constituents. The additive of the type of Example 3, because of the increased amount of manganese present therein, is particularly desirable for use where combustion problems, and particularly the minimization of the formation of sulphur trioxide, are of significance. The presence of the second and third constituents greatly enhances the known action of the manganese-containing compounds as a slag modifier, oil-ash corrosion inhibitor, and particularly as a low temperature inhibitor for the conversion of sulphur dioxide to sulphur trioxide, and

with the presence of the manganese in appreciable amounts, higher amounts of iron-containing compounds appear to be called for.

Additives of the type of Example 1, in which an aluminum-containing compound constitutes the first additive constituent, appear to give best results where ash production is the major problem. Additives of the type of Example 2, in which a magnesium-containing compound constitutes the first constituent, appear to be preferable where corrosion is the major factor and where turbines are involved. Additives of the type of Example 3, where manganese-containing compounds constitute the first constituent are desirable where more efficient fuel burning is the major desideratum.

Through the use of the combinative additive in fuel compositions of the present invention, one is enabled to use appreciably small amounts of additive compounds than has previously been the case, and such com-

pounds may be employed even when the sodium chloride content of the fuel is relatively high, a factor which normally is considered as adversely affecting the action of additives. It is further noteworthy that iron compounds, usually considered undesirable because of their tendency to form low melting point slags, are very decidedly advantageous in connection with the present invention.

Despite the fact that smaller amounts of additive material that is customary are employed in accordance with the present invention, the beneficial results achieved thereby are superior to, and more dependably attained, than those which attend prior art additives. Thus better and more reliable results are achieved in accordance with the present invention, at a lesser cost and without the secondary effects which have militated against prior art suggestions along these lines.

While but a limited number of embodiments of the present invention are here specifically disclosed, it will be apparent that many variations may be made therein, all within the scope of the invention as defined in the following claims.

#### WHAT WE CLAIM IS:—

1. A fuel composition having improved slag-forming characteristics comprising a major amount of a fuel from a class consisting of residual petroleum fuel, coal and coke, the fuel containing vanadium, sulphur and/or sodium and a minor amount of an additive comprising a first constituent which consists of one of the elements aluminum, magnesium and manganese or a compound or compounds of said one element, a second constituent which consists of one of said elements or a compound or compounds thereof of the class comprising said first constituent not being the element or a compound or compounds thereof selected as said first constituent, and a third constituent which consists of the element iron or a compound or compounds thereof, said first constituent being present in the additive in active element proportions as hereinbefore defined of from 5 to 30 parts by weight, said second and third constituents both being present in the additive in active element proportions as hereinbefore defined of from 0.35 to 10 parts by weight, the active element proportions in which the first constituent is present being greater than the active element proportions in which either of the second and third constituents is present, said active element proportions being based on 100 parts by weight of the additive, said additive being effective to minimize the deleterious effects of said vanadium, sulphur and/or sodium when combustion of said fuel occurs.

2. The fuel composition of Claim 1, in which said aluminum is in the form of alumina, said magnesium is in the form of oxides, hydroxides or carbonates of magnesium, said manganese is in the form of manganese di-

oxide or manganese-containing clays, and said iron is in the form of oxides or carbonates of iron.

3. The fuel composition of either of Claims 1 and 2, in which said first and third constituents are in the form of particles having a size between 0.1 and 15 microns.

4. The fuel composition of either of Claims 1 and 2, in which said aluminum and its compounds are in the form of particles having a size between 0.5 and 3 microns, said iron and its compounds are in the form of particles having a particle size between 0.1 and 10 microns, said manganese and its compounds are in the form of particles having a size between 0.1 and 15 microns, and said magnesium and its compounds are in finely divided form.

5. The fuel composition of any of Claims 1—4, in which said first constituent is present in active element proportions of from 9 to 20 parts by weight and said second and third constituents are each present in active element proportions by weight between 0.6 and 4 parts.

6. The fuel composition of any of Claims 1—4, in which said first constituent comprises aluminum and is present in active element proportions by weight between 9 and 15 parts, said second constituent comprises manganese and is present in active element proportions by weight between 0.9 and 3 parts, and said third constituent comprises iron and is present in active element proportions by weight between 0.6 and 2 parts.

7. The fuel composition of any of Claims 1—4, in which said first constituent comprises magnesium and is present in active element proportions by weight between 15—20 parts, said second constituent comprises manganese and is present in active element proportions by weight between 0.9 and 3 parts, and said third constituent comprises iron and is present in active element proportions by weight between 0.6 and 2 parts.

8. The fuel composition of any of Claims 1—4, in which said first constituent comprises manganese and is present in active element proportions by weight between 9 and 15 parts, said second constituent comprises aluminum and is present in active element proportions by weight between 0.6 and 3 parts, and said third constituent comprises iron and is present in active element proportions by weight between 1 and 4 parts.

9. The fuel composition of any of Claims 1—8, in which said fuel has a vanadium content and said additive and said fuel are present in proportions such, and said first, second and third constituents are present in said additive in proportions such, as to produce in the mixture substantially the following weight ratios of active constituent element to vanadium element: first constituent—1:2, second and third constituents—1:14—20.



5 10. The method of minimizing the deleterious effects of vanadium, sulphur and sodium in fuel compositions from the class consisting of residual petroleum, coal and coke which comprises burning said fuel in the presence of a minor amount, relative to said fuel, of the additive specified in any of Claims 1—9.

10 11. A fuel composition substantially as hereinbefore described with reference to the Examples.

12. The method of minimizing the deleterious effects of vanadium, sulphur and sodium in fuel compositions substantially as hereinbefore described with reference to the Examples. 15

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